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44.1 F2XM1—Compute 2^x-1

Opcode	Instruction	Description
D9 F0	F2XM1	Replace ST(0) with $(2^{ST(0)} - 1)$

Description

Calculates the exponential value of 2 to the power of the source operand minus 1. The source operand is located in register ST(0) and the result is also stored in ST(0). The value of the source operand must lie in the range –1.0 to +1.0. If the source value is outside this range, the result is undefined.

The following table shows the results obtained when computing the exponential value of various classes of numbers, assuming that neither overflow nor underflow occurs.

ST(0) SRC	ST(0) DEST
–1.0 to –0	–0.5 to –0
–0	–0
+0	+0
+0 to +1.0	+0 to 1.0

Values other than 2 can be exponentiated using the following formula:

$x^y = 2^{(y * \log_2 x)}$

Operation

$ST(0) \leftarrow (2^{ST(0)} - 1);$

FPU Flags Affected

C1 — Set to 0 if stack underflow occurred.

Indicates rounding direction if the inexact-result exception (#P) is generated: 0 = not roundup; 1 = roundup.

C0, C2, C3 — Undefined.

Floating-Point Exceptions

#IS — Stack underflow occurred.

#IA — Source operand is an SNaN value or unsupported format.

#D — Result is a denormal value.

#U — Result is too small for destination format.

#P Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.2 FABS—Absolute Value

Opcode	Instruction	Description
D9 E1	FABS	Replace ST with its absolute value.

Description

Clears the sign bit of ST(0) to create the absolute value of the operand. The following table shows the results obtained when creating the absolute value of various classes of numbers.

ST(0) SRC	ST(0) DEST
-•	+∞
–F	+F
–0	+0
+0	+0
+F	+F
+∞	+∞
NaN	NaN

NOTE: F Means finite-real number.

Operation

```
ST(0) ← |ST(0)|
```

FPU Flags Affected

C1 Set to 0 if stack underflow occurred; otherwise, cleared to 0.

C0, C2, C3 Undefined.

Floating-Point Exceptions

#IS Stack underflow occurred.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.3 FADD/FADDP/FIADD—Add

Opcode	Instruction	Description
D8 /0	FADD *m32 real*	Add *m32real* to ST(0) and store result in ST(0)
DC /0	FADD *m64real*	Add *m64real* to ST(0) and store result in ST(0)
D8 C0+i	FADD ST(0), ST(i)	Add ST(0) to ST(i) and store result in ST(0)
DC C0+i	FADD ST(i), ST(0)	Add ST(i) to ST(0) and store result in ST(i)
DE C0+i	FADDP ST(i), ST(0)	Add ST(0) to ST(i), store result in ST(i), and pop the register stack
DE C1	FADDP	Add ST(0) to ST(1), store result in ST(1), and pop the register stack
DA /0	FIADD *m32int*	Add *m32int* to ST(0) and store result in ST(0)
DE /0	FIADD *m16int*	Add *m16int* to ST(0) and store result in ST(0)

Description

Adds the destination and source operands and stores the sum in the destination location. The destination operand is always an FPU register; the source operand can be a register or a memory location. Source operands in memory can be in single-real, double-real, word-integer, or short-integer formats.

The no-operand version of the instruction adds the contents of the ST(0) register to the ST(1) register. The one-operand version adds the contents of a memory location (either a real or an integer value) to the contents of the ST(0) register. The two-operand version, adds the contents of the ST(0) register to the ST(i) register or vice versa. The value in ST(0) can be doubled by coding:

```
FADD ST(0), ST(0);
```

The FADDP instructions perform the additional operation of popping the FPU register stack after storing the result. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1. (The no-operand version of the floating-point add instructions always results in the register stack being popped. In some assemblers, the mnemonic for this instruction is FADD rather than FADDP.)

The FIADD instructions convert an integer source operand to extended-real format before performing the addition.

The table on the following page shows the results obtained when adding various classes of numbers, assuming that neither overflow nor underflow occurs.

When the sum of two operands with opposite signs is 0, the result is +0, except for the round toward –∞ mode, in which case the result is –0. When the source operand is an integer 0, it is treated as a +0.

When both operand are infinities of the same sign, the result is ∞ of the expected sign. If both operands are infinities of opposite signs, an invalid-operation exception is generated.

		DEST						
		-•	–F	–0	+0	+F	+∞	NaN
SRC	-∞	-∞	-∞	-∞	-∞	-∞	*	NaN
	–F or –I	-∞	–F	SRC	SRC	±F or ±0	+∞	NaN
	–0	-∞	DEST	–0	±0	DEST	+∞	NaN
	+0	-∞	DEST	±0	+0	DEST	+∞	NaN
	+F or +I	-∞	±F or ±0	SRC	SRC	+F	+∞	NaN
	+∞	*	+∞	+∞	+∞	+∞	+∞	NaN
	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

NOTES:
1. FMeans finite-real number.
2. IMeans integer.
3. *Indicates floating-point invalid-arithmetic-operand (#IA) exception.

Operation

```
IF instruction is FIADD
    THEN
        DEST ← DEST + ConvertExtendedReal(SRC);
    ELSE (* source operand is real number *)
        DEST ← DEST + SRC;
FI;
IF instruction = FADDP
    THEN
        PopRegisterStack;
FI;
```

FPU Flags Affected

C1 — Set to 0 if stack underflow occurred.

Indicates rounding direction if the inexact-result exception (#P) is generated: 0 = not roundup; 1 = roundup.

C0, C2, C3 — Undefined.

Floating-Point Exceptions

#IS — Stack underflow occurred.

#IA — Operand is an SNaN value or unsupported format.

Operands are infinities of unlike sign.

#D — Result is a denormal value.

#U — Result is too small for destination format.

#O — Result is too large for destination format.

#P — Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.4 FBLD—Load Binary Coded Decimal

Opcode	Instruction	Description
DF /4	FBLD *m80 dec*	Convert BCD value to real and push onto the FPU stack.

Description

Converts the BCD source operand into extended-real format and pushes the value onto the FPU stack. The source operand is loaded without rounding errors. The sign of the source operand is preserved, including that of –0.

The packed BCD digits are assumed to be in the range 0 through 9; the instruction does not check for invalid digits (AH through FH). Attempting to load an invalid encoding produces an undefined result.

Operation

```
TOP ← TOP – 1;
```

```
ST(0) ← ExtendedReal(SRC);
```

FPU Flags Affected

C1	Set to 1 if stack overflow occurred; otherwise, cleared to 0.
C0, C2, C3	Undefined.

Floating-Point Exceptions

#IS	Stack overflow occurred.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.5 FBSTP—Store BCD Integer and Pop

Opcode	Instruction	Description
DF /6	FBSTP m80bcd	Store ST(0) in m80bcd and pop ST(0).

Description

Converts the value in the ST(0) register to an 18-digit packed BCD integer, stores the result in the destination operand, and pops the register stack. If the source value is a non-integral value, it is rounded to an integer value, according to rounding mode specified by the RC field of the FPU control word. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1.

The destination operand specifies the address where the first byte destination value is to be stored. The BCD value (including its sign bit) requires 10 bytes of space in memory.

The following table shows the results obtained when storing various classes of numbers in packed BCD format.

ST(0)	DEST
-∞	*
–F < –1	–D
–1 < –F < –0	**
–0	–0
+0	+0
+0 < +F < +1	**
+F > +1	+D
+∞	*
NaN	*

NOTES:

F Means finite-real number.
D Means packed-BCD number.
* Indicates floating-point invalid-operation (#IA) exception.
** ±0 or ±1, depending on the rounding mode.

If the source value is too large for the destination format and the invalid-operation exception is not masked, an invalid-operation exception is generated and no value is stored in the destination operand. If the invalid-operation exception is masked, the packed BCD indefinite value is stored in memory.

If the source value is a quiet NaN, an invalid-operation exception is generated. Quiet NaNs do not normally cause this exception to be generated.

Operation

```
DEST ← BCD(ST(0));
PopRegisterStack;
```

FPU Flags Affected

C1	Set to 0 if stack underflow occurred.
	Indicates rounding direction if the inexact exception (#P) is generated: 0 = not roundup; 1 = roundup.
C0, C2, C3	Undefined.

Floating-Point Exceptions

#IS	Stack underflow occurred.
#IA	Source operand is empty; contains a NaN, ±∞, or unsupported format; or contains value that exceeds 18 BCD digits in length.
#P	Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#GP(0)	If a segment register is being loaded with a segment selector that points to a nonwritable segment.
	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.6 FCHS—Change Sign

Opcode	Instruction	Description
D9 E0	FCHS	Complements sign of ST(0)

Description

Complements the sign bit of ST(0). This operation changes a positive value into a negative value of equal magnitude or vice versa. The following table shows the results obtained when changing the sign of various classes of numbers.

ST(0) SRC	ST(0) DEST
-•	+∞
–F	+F
–0	+0
+0	–0
+F	–F
+∞	-•
NaN	NaN

NOTE: F Means finite-real number.

Operation

```
SignBit(ST(0)) ← NOT (SignBit(ST(0)))
```

FPU Flags Affected

C1 Set to 0 if stack underflow occurred; otherwise, cleared to 0.

C0, C2, C3 Undefined.

Floating-Point Exceptions

#IS Stack underflow occurred.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.7 FCLEX/FNCLEX—Clear Exceptions

Opcode	Instruction	Description
9B DB E2	FCLEX	Clear floating-point exception flags after checking for pending unmasked floating-point exceptions.
DB E2	FNCLEX*	Clear floating-point exception flags without checking for pending unmasked floating-point exceptions.

NOTE: * See “Intel Architecture Compatibility” below.

Description

Clears the floating-point exception flags (PE, UE, OE, ZE, DE, and IE), the exception summary status flag (ES), the stack fault flag (SF), and the busy flag (B) in the FPU status word. The FCLEX instruction checks for and handles any pending unmasked floating-point exceptions before clearing the exception flags; the FNCLEX instruction does not.

Intel Architecture Compatibility

When operating a Pentium or Intel486 processor in MS-DOS compatibility mode, it is possible (under unusual circumstances) for an FNCLEX instruction to be interrupted prior to being executed to handle a pending FPU exception. See the section titled “No-Wait FPU Instructions Can Get FPU Interrupt in Window”, for a description of these circumstances. An FNCLEX instruction cannot be interrupted in this way on a Pentium Pro processor.

Operation

```
FPUStatusWord[0..7] ← 0;
FPUStatusWord[15] ← 0;
```

FPU Flags Affected

The PE, UE, OE, ZE, DE, IE, ES, SF, and B flags in the FPU status word are cleared. The C0, C1, C2, and C3 flags are undefined.

Floating-Point Exceptions

None.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.8 FCMOV*cc*—Floating-Point Conditional Move

Opcode	Instruction	Description
DA C0+i	FCMOVB ST(0), ST(i)	Move if below (CF=1)
DA C8+i	FCMOVE ST(0), ST(i)	Move if equal (ZF=1)
DA D0+i	FCMOVBE ST(0), ST(i)	Move if below or equal (CF=1 or ZF=1)
DA D8+i	FCMOVU ST(0), ST(i)	Move if unordered (PF=1)
DB C0+i	FCMOVNB ST(0), ST(i)	Move if not below (CF=0)
DB C8+i	FCMOVNE ST(0), ST(i)	Move if not equal (ZF=0)
DB D0+i	FCMOVNBE ST(0), ST(i)	Move if not below or equal (CF=0 and ZF=0)
DB D8+i	FCMOVNU ST(0), ST(i)	Move if not unordered (PF=0)

Description

Tests the status flags in the EFLAGS register and moves the source operand (second operand) to the destination operand (first operand) if the given test condition is true. The conditions for each mnemonic are given in the Description column above and in “Conditional Jump Instructions”. The source operand is always in the ST(i) register and the destination operand is always ST(0).

The FCMOV*cc* instructions are useful for optimizing small IF constructions. They also help eliminate branching overhead for IF operations and the possibility of branch mispredictions by the processor.

A processor may not support the FCMOV*cc* instructions. Software can check if the FCMOV*cc* instructions are supported by checking the processor’s feature information with the CPUID instruction (see “CPUID—CPU Identification” in this chapter). If both the CMOV and FPU feature bits are set, the FCMOV*cc* instructions are supported.

Intel Architecture Compatibility

The FCMOVcc instructions were introduced to the Intel Architecture in the Pentium Pro processor family and is not available in earlier Intel Architecture processors.

Operation

```
IF condition TRUE
    ST(0) ← ST(i)
FI;
```

FPU Flags Affected

C1 Set to 0 if stack underflow occurred.

C0, C2, C3 Undefined.

Floating-Point Exceptions

#IS Stack underflow occurred.

Integer Flags Affected

None.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.9 FCOM/FCOMP/FCOMPP—Compare Real

Opcode	Instruction	Description
D8 /2	FCOM *m32real*	Compare ST(0) with *m32real*.
DC /2	FCOM *m64real*	Compare ST(0) with *m64real*.
D8 D0+i	FCOM ST(i)	Compare ST(0) with ST(i).
D8 D1	FCOM	Compare ST(0) with ST(1).
D8 /3	FCOMP *m32real*	Compare ST(0) with *m32real* and pop register stack.
DC /3	FCOMP *m64real*	Compare ST(0) with m64real and pop register stack.
D8 D8+i	FCOMP ST(i)	Compare ST(0) with ST(i) and pop register stack.
D8 D9	FCOMP	Compare ST(0) with ST(1) and pop register stack.
DE D9	FCOMPP	Compare ST(0) with ST(1) and pop register stack twice.

Description

Compares the contents of register ST(0) and source value and sets condition code flags C0, C2, and C3 in the FPU status word according to the results (see the table below). The source operand can be a data register or a memory location. If no source operand is given, the value in ST(0) is compared with the value in ST(1). The sign of zero is ignored, so that –0.0 = +0.0.

Condition	C3	C2	C0
ST(0) > SRC	0	0	0
ST(0) < SRC	0	0	1
ST(0) = SRC	1	0	0
Unordered*	1	1	1

NOTE: *Flags not set if unmasked invalid-arithmetic-operand (#IA) exception is generated.

This instruction checks the class of the numbers being compared (see “FXAM—Examine” in this chapter). If either operand is a NaN or is in an unsupported format, an invalid-arithmetic-operand exception (#IA) is raised and, if the exception is masked, the condition flags are set to “unordered.” If the invalid-arithmetic-operand exception is unmasked, the condition code flags are not set.

The FCOMP instruction pops the register stack following the comparison operation and the FCOMPP instruction pops the register stack twice following the comparison operation. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1.

The FCOM instructions perform the same operation as the FUCOM instructions. The only difference is how they handle QNaN operands. The FCOM instructions raise an invalid-arithmetic-operand exception (#IA) when either or both of the operands is a NaN value or is in an unsupported format. The FUCOM instructions perform the same operation as the FCOM instructions, except that they do not generate an invalid-arithmetic-operand exception for QNaNs.

Operation

```
CASE (relation of operands) OF
    ST > SRC:        C3, C2, C0 ← 000;
    ST < SRC:        C3, C2, C0 ← 001;
    ST = SRC:        C3, C2, C0 ← 100;
ESAC;
IF ST(0) or SRC = NaN or unsupported format
    THEN
        #IA
        IF FPUControlWord.IM = 1
            THEN
                C3, C2, C0 ← 111;
        FI;
FI;
IF instruction = FCOMP
    THEN
        PopRegisterStack;
FI;
IF instruction = FCOMPP
    THEN
        PopRegisterStack;
        PopRegisterStack;
FI;
```

FPU Flags Affected

C1	Set to 0 if stack underflow occurred; otherwise, cleared to 0.
C0, C2, C3	See table on previous page.

Floating-Point Exceptions

#IS	Stack underflow occurred.
#IA	One or both operands are NaN values or have unsupported formats.
	Register is marked empty.
#D	One or both operands are denormal values.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.10 FCOMI/FCOMIP/FUCOMI/FUCOMIP—Compare Real and Set EFLAGS

Opcode	Instruction	Description
DB F0+i	FCOMI ST, ST(i)	Compare ST(0) with ST(i) and set status flags accordingly
DF F0+i	FCOMIP ST, ST(i)	Compare ST(0) with ST(i), set status flags accordingly, and pop register stack
DB E8+i	FUCOMI ST, ST(i)	Compare ST(0) with ST(i), check for ordered values, and set status flags accordingly
DF E8+i	FUCOMIP ST, ST(i)	Compare ST(0) with ST(i), check for ordered values, set status flags accordingly, and pop register stack

Description

Compares the contents of register ST(0) and ST(i) and sets the status flags ZF, PF, and CF in the EFLAGS register according to the results (see the table below). The sign of zero is ignored for comparisons, so that –0.0 = +0.0.

Comparison Results	ZF	PF	CF
ST0 > ST(i)	0	0	0
ST0 < ST(i)	0	0	1
ST0 = ST(i)	1	0	0
Unordered*	1	1	1

NOTE: *Flags not set if unmasked invalid-arithmetic-operand (#IA) exception is generated.

The FCOMI/FCOMIP instructions perform the same operation as the FUCOMI/FUCOMIP instructions. The only difference is how they handle QNaN operands. The FCOMI/FCOMIP instructions set the status flags to “unordered” and generate an invalid-arithmetic-operand exception (#IA) when either or both of the operands is a NaN value (SNaN or QNaN) or is in an unsupported format.

The FUCOMI/FUCOMIP instructions perform the same operation as the FCOMI/FCOMIP instructions, except that they do not generate an invalid-arithmetic-operand exception for QNaNs. See “FXAM—Examine” in this chapter for additional information on unordered comparisons.

If invalid-operation exception is unmasked, the status flags are not set if the invalid-arithmetic-operand exception is generated.

The FCOMIP and FUCOMIP instructions also pop the register stack following the comparison operation. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1.

Intel Architecture Compatibility

The FCOMI/FCOMIP/FUCOMI/FUCOMIP instructions were introduced to the Intel Architecture in the Pentium Pro processor family and are not available in earlier Intel Architecture processors.

Operation

```
CASE (relation of operands) OF
    ST(0) > ST(i):   ZF, PF, CF ← 000;
    ST(0) < ST(i):   ZF, PF, CF ← 001;
    ST(0) = ST(i):   ZF, PF, CF ← 100;
ESAC;
IF instruction is FCOMI or FCOMIP
    THEN
        IF ST(0) or ST(i) = NaN or unsupported format
            THEN
                #IA
                IF FPUControlWord.IM = 1
                    THEN
                        ZF, PF, CF ← 111;
                FI;
        FI;
FI;
IF instruction is FUCOMI or FUCOMIP
    THEN
        IF ST(0) or ST(i) = QNaN, but not SNaN or unsupported format
            THEN
                ZF, PF, CF ← 111;
            ELSE (* ST(0) or ST(i) is SNaN or unsupported format *)
                 #IA;
                IF FPUControlWord.IM = 1
                    THEN
                        ZF, PF, CF ← 111;
                FI;
        FI;
FI;
IF instruction is FCOMIP or FUCOMIP
    THEN
        PopRegisterStack;
FI;
```

FPU Flags Affected

C1	Set to 0 if stack underflow occurred; otherwise, cleared to 0.
C0, C2, C3	Not affected.

Floating-Point Exceptions

#IS	Stack underflow occurred.

#IA (FCOMI or FCOMIP instruction) One or both operands are NaN values or have unsupported formats.

(FUCOMI or FUCOMIP instruction) One or both operands are SNaN values (but not QNaNs) or have undefined formats. Detection of a QNaN value does not raise an invalid-operand exception.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.11 FCOS—Cosine

Opcode	Instruction	Description
D9 FF	FCOS	Replace ST(0) with its cosine

Description

Calculates the cosine of the source operand in register ST(0) and stores the result in ST(0). The source operand must be given in radians and must be within the range -2^{63} to $+2^{63}$. The following table shows the results obtained when taking the cosine of various classes of numbers, assuming that neither overflow nor underflow occurs.

ST(0) SRC	ST(0) DEST
-•	*
–F	–1 to +1
–0	+1
+0	+1
+F	–1 to +1
+∞	*
NaN	NaN

F Means finite-real number.
* Indicates floating-point invalid-arithmetic-operand (#IA) exception.

If the source operand is outside the acceptable range, the C2 flag in the FPU status word is set, and the value in register ST(0) remains unchanged. The instruction does not raise an exception when the source operand is out of range. It is up to the program to check the C2 flag for out-of-range conditions. Source values outside the range -2^{63} to $+2^{63}$ can be reduced to the range of the

instruction by subtracting an appropriate integer multiple of 2π or by using the FPREM instruction with a divisor of 2π. See “Pi”, for a discussion of the proper value to use for π in performing such reductions.

Operation

```
IF |ST(0)| < 2^63
THEN
    C2 ← 0;
    ST(0) ← cosine(ST(0));
ELSE (*source operand is out-of-range *)
    C2 ← 1;
FI;
```

FPU Flags Affected

C1	Set to 0 if stack underflow occurred.
	Indicates rounding direction if the inexact-result exception (#P) is generated: 0 = not roundup; 1 = roundup.
	Undefined if C2 is 1.
C2	Set to 1 if source operand is outside the range -2^{63} to $+2^{63}$; otherwise, cleared to 0.
C0, C3	Undefined.

Floating-Point Exceptions

#IS	Stack underflow occurred.
#IA	Source operand is an SNaN value, ∞, or unsupported format.
#D	Result is a denormal value.
#U	Result is too small for destination format.
#P	Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#NM	EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM	EM or TS in CR0 is set.

44.12 FDECSTP—Decrement Stack-Top Pointer

Opcode	Instruction	Description
D9 F6	FDECSTP	Decrement TOP field in FPU status word.

Description

Subtracts one from the TOP field of the FPU status word (decrements the top-of-stack pointer). If the TOP field contains a 0, it is set to 7. The effect of this instruction is to rotate the stack by one position. The contents of the FPU data registers and tag register are not affected.

Operation

```
IF TOP = 0
    THEN TOP ← 7;
    ELSE TOP ← TOP – 1;
FI;
```

FPU Flags Affected

The C1 flag is set to 0; otherwise, cleared to 0. The C0, C2, and C3 flags are undefined.

Floating-Point Exceptions

None.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.13 FDIV/FDIVP/FIDIV—Divide

Opcode	Instruction	Description
D8 /6	FDIV *m32real*	Divide ST(0) by *m32real* and store result in ST(0)
DC /6	FDIV *m64real*	Divide ST(0) by *m64real* and store result in ST(0)
D8 F0+i	FDIV ST(0), ST(i)	Divide ST(0) by ST(i) and store result in ST(0)
DC F8+i	FDIV ST(i), ST(0)	Divide ST(i) by ST(0) and store result in ST(i)
DE F8+i	FDIVP ST(i), ST(0)	Divide ST(i) by ST(0), store result in ST(i), and pop the register stack
DE F9	FDIVP	Divide ST(1) by ST(0), store result in ST(1), and pop the register stack
DA /6	FIDIV *m32int*	Divide ST(0) by *m32int* and store result in ST(0)
DE /6	FIDIV *m16int*	Divide ST(0) by *m64int* and store result in ST(0)

Description

Divides the destination operand by the source operand and stores the result in the destination location. The destination operand (dividend) is always in an FPU register; the source operand (divisor) can be a register or a memory location. Source operands in memory can be in single-real, double-real, word-integer, or short-integer formats.

The no-operand version of the instruction divides the contents of the ST(1) register by the contents of the ST(0) register. The one-operand version divides the contents of the ST(0) register by the contents of a memory location (either a real or an integer value). The two-operand version, divides the contents of the ST(0) register by the contents of the ST(i) register or vice versa.

The FDIVP instructions perform the additional operation of popping the FPU register stack after storing the result. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1. The no-operand version of the floating-point divide instructions always results in the register stack being popped. In some assemblers, the mnemonic for this instruction is FDIV rather than FDIVP.

The FIDIV instructions convert an integer source operand to extended-real format before performing the division. When the source operand is an integer 0, it is treated as a +0.

If an unmasked divide by zero exception (#Z) is generated, no result is stored; if the exception is masked, an ∞ of the appropriate sign is stored in the destination operand.

The following table shows the results obtained when dividing various classes of numbers, assuming that neither overflow nor underflow occurs.

		DEST						
		-•	–F	–0	+0	+F	+∞	NaN
SRC	-∞	*	+0	+0	–0	–0	*	NaN
	–F	+∞	+F	+0	–0	–F	-•	NaN
	–I	+∞	+F	+0	–0	–F	-•	NaN
	–0	+∞	**	*	*	**	-•	NaN
	+0	-•	**	*	*	**	+∞	NaN
	+I	-•	–F	–0	+0	+F	+∞	NaN
	+F	-•	–F	–0	+0	+F	+∞	NaN
	+∞	*	–0	–0	+0	+0	*	NaN
	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

F Means finite-real number.
I Means integer.
* Indicates floating-point invalid-arithmetic-operand (#IA) exception.
** Indicates floating-point zero-divide (#Z) exception.

Operation

```
IF SRC = 0
    THEN
        #Z
    ELSE
        IF instruction is FIDIV
            THEN
                DEST ← DEST / ConvertExtendedReal(SRC);
            ELSE (* source operand is real number *)
                DEST ← DEST / SRC;
```

```
        FI;
FI;
IF instruction = FDIVP
    THEN
        PopRegisterStack
FI;
```

FPU Flags Affected

C1	Set to 0 if stack underflow occurred.
	Indicates rounding direction if the inexact-result exception (#P) is generated: 0 = not roundup; 1 = roundup.
C0, C2, C3	Undefined.

Floating-Point Exceptions

#IS	Stack underflow occurred.
#IA	Operand is an SNaN value or unsupported format.
	$\pm\infty / \pm\infty$; $\pm 0 / \pm 0$
#D	Result is a denormal value.
#Z	DEST / ± 0, where DEST is not equal to ± 0.
#U	Result is too small for destination format.
#O	Result is too large for destination format.
#P	Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.

#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.14 FDIVR/FDIVRP/FIDIVR—Reverse Divide

Opcode	Instruction	Description
D8 /7	FDIVR *m32real*	Divide *m32real* by ST(0) and store result in ST(0)
DC /7	FDIVR *m64real*	Divide *m64real* by ST(0) and store result in ST(0)
D8 F8+i	FDIVR ST(0), ST(i)	Divide ST(i) by ST(0) and store result in ST(0)
DC F0+i	FDIVR ST(i), ST(0)	Divide ST(0) by ST(i) and store result in ST(i)
DE F0+i	FDIVRP ST(i), ST(0)	Divide ST(0) by ST(i), store result in ST(i), and pop the register stack
DE F1	FDIVRP	Divide ST(0) by ST(1), store result in ST(1), and pop the register stack
DA /7	FIDIVR *m32int*	Divide *m32int* by ST(0) and store result in ST(0)
DE /7	FIDIVR *m16int*	Divide *m64int* by ST(0) and store result in ST(0)

Description

Divides the source operand by the destination operand and stores the result in the destination location. The destination operand (divisor) is always in an FPU register; the source operand (dividend) can be a register or a memory location. Source operands in memory can be in single-real, double-real, word-integer, or short-integer formats.

These instructions perform the reverse operations of the FDIV, FDIVP, and FIDIV instructions. They are provided to support more efficient coding.

The no-operand version of the instruction divides the contents of the ST(0) register by the contents of the ST(1) register. The one-operand version divides the contents of a memory location (either a real or an integer value) by the contents of the ST(0) register. The two-operand version, divides the contents of the ST(i) register by the contents of the ST(0) register or vice versa.

The FDIVRP instructions perform the additional operation of popping the FPU register stack after storing the result. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1. The no-operand version of the floating-point divide instructions always results in the register stack being popped. In some assemblers, the mnemonic for this instruction is FDIVR rather than FDIVRP.

The FIDIVR instructions convert an integer source operand to extended-real format before performing the division.

If an unmasked divide by zero exception (#Z) is generated, no result is stored; if the exception is masked, an ∞ of the appropriate sign is stored in the destination operand.

The following table shows the results obtained when dividing various classes of numbers, assuming that neither overflow nor underflow occurs.

		DEST						
		-•	–F	–0	+0	+F	+∞	NaN
SRC	-•	*	+∞	+∞	-•	-•	*	NaN
	–F	+0	+F	**	**	-F	–0	NaN
	–I	+0	+F	**	**	-F	–0	NaN
	–0	+0	+0	*	*	–0	–0	NaN
	+0	–0	–0	*	*	+0	+0	NaN
	+I	–0	-F	**	**	+F	+0	NaN
	+F	–0	-F	**	**	+F	+0	NaN
	+∞	*	-•	-•	+∞	+∞	*	NaN
	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

NOTES:
1. FMeans finite-real number.
2. IMeans integer.
3. *Indicates floating-point invalid-arithmetic-operand (#IA) exception.
4. ** Indicates floating-point zero-divide (#Z) exception.

When the source operand is an integer 0, it is treated as a +0.

Operation

```
IF DEST = 0
    THEN
        #Z
    ELSE
        IF instruction is FIDIVR
            THEN
                DEST ← ConvertExtendedReal(SRC) / DEST;
            ELSE (* source operand is real number *)
                DEST ← SRC / DEST;
        FI;
FI;
IF instruction = FDIVRP
    THEN
        PopRegisterStack
FI;
```

FPU Flags Affected

C1 — Set to 0 if stack underflow occurred.

Indicates rounding direction if the inexact-result exception (#P) is generated: 0 = not roundup; 1 = roundup.

C0, C2, C3 — Undefined.

Floating-Point Exceptions

#IS — Stack underflow occurred.

#IA — Operand is an SNaN value or unsupported format.

±∞ / ±∞; ±0 / ±0

#D — Result is a denormal value.

#Z — SRC / ±0, where SRC is not equal to ±0.

#U	Result is too small for destination format.
#O	Result is too large for destination format.
#P	Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.15 FFREE—Free Floating-Point Register

Opcode	Instruction	Description
DD C0+i	FFREE ST(i)	Sets tag for ST(i) to empty

Description

Sets the tag in the FPU tag register associated with register ST(i) to empty (11B). The contents of ST(i) and the FPU stack-top pointer (TOP) are not affected.

Operation

```
TAG(i) ← 11B;
```

FPU Flags Affected

C0, C1, C2, C3 undefined.

Floating-Point Exceptions

None.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.16 FICOM/FICOMP—Compare Integer

Opcode	Instruction	Description
DE /2	FICOM *m16int*	Compare ST(0) with *m16int*
DA /2	FICOM *m32int*	Compare ST(0) with *m32int*
DE /3	FICOMP *m16int*	Compare ST(0) with *m16int* and pop stack register
DA /3	FICOMP *m32int*	Compare ST(0) with *m32int* and pop stack register

Description

Compares the value in ST(0) with an integer source operand and sets the condition code flags C0, C2, and C3 in the FPU status word according to the results (see table below). The integer value is converted to extended-real format before the comparison is made.

Condition	C3	C2	C0
ST(0) > SRC	0	0	0
ST(0) < SRC	0	0	1
ST(0) = SRC	1	0	0
Unordered	1	1	1

These instructions perform an “unordered comparison.” An unordered comparison also checks the class of the numbers being compared (see “FXAM—Examine” in this chapter). If either operand is a NaN or is in an undefined format, the condition flags are set to “unordered.”

The sign of zero is ignored, so that –0.0 = +0.0.

The FICOMP instructions pop the register stack following the comparison. To pop the register stack, the processor marks the ST(0) register empty and increments the stack pointer (TOP) by 1.

Operation

```
CASE (relation of operands) OF
    ST(0) > SRC:     C3, C2, C0 ← 000;
    ST(0) < SRC:     C3, C2, C0 ← 001;
    ST(0) = SRC:     C3, C2, C0 ← 100;
    Unordered:       C3, C2, C0 ← 111;
ESAC;
IF instruction = FICOMP
    THEN
        PopRegisterStack;
FI;
```

FPU Flags Affected

C1	Set to 0 if stack underflow occurred; otherwise, set to 0.
C0, C2, C3	See table on previous page.

Floating-Point Exceptions

#IS	Stack underflow occurred.
#IA	One or both operands are NaN values or have unsupported formats.
#D	One or both operands are denormal values.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.17 FILD—Load Integer

Opcode	Instruction	Description
DF /0	FILD *m16int*	Push *m16int* onto the FPU register stack.
DB /0	FILD *m32int*	Push *m32int* onto the FPU register stack.
DF /5	FILD *m64int*	Push *m64int* onto the FPU register stack.

Description

Converts the signed-integer source operand into extended-real format and pushes the value onto the FPU register stack. The source operand can be a word, short, or long integer value. It is loaded without rounding errors. The sign of the source operand is preserved.

Operation

```
TOP ← TOP – 1;
ST(0) ← ExtendedReal(SRC);
```

FPU Flags Affected

C1	Set to 1 if stack overflow occurred; cleared to 0 otherwise.
C0, C2, C3	Undefined.

Floating-Point Exceptions

#IS	Stack overflow occurred.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.

#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.18 FINCSTP—Increment Stack-Top Pointer

Opcode	Instruction	Description
D9 F7	FINCSTP	Increment the TOP field in the FPU status register

Description

Adds one to the TOP field of the FPU status word (increments the top-of-stack pointer). If the TOP field contains a 7, it is set to 0. The effect of this instruction is to rotate the stack by one position. The contents of the FPU data registers and tag register are not affected. This operation is not equivalent to popping the stack, because the tag for the previous top-of-stack register is not marked empty.

Operation

```
IF TOP = 7
    THEN TOP ← 0;
    ELSE TOP ← TOP + 1;
FI;
```

FPU Flags Affected

The C1 flag is set to 0; otherwise, cleared to 0. The C0, C2, and C3 flags are undefined.

Floating-Point Exceptions

None.

Protected Mode Exceptions

#NM	EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM	EM or TS in CR0 is set.

44.19 FINIT/FNINIT—Initialize Floating-Point Unit

Opcode	Instruction	Description
9B DB E3	FINIT	Initialize FPU after checking for pending unmasked floating-point exceptions.
DB E3	FNINIT*	Initialize FPU without checking for pending unmasked floating-point exceptions.

NOTE: * See “Intel Architecture Compatibility” below.

Description

Sets the FPU control, status, tag, instruction pointer, and data pointer registers to their default states. The FPU control word is set to 037FH (round to nearest, all exceptions masked, 64-bit precision). The status word is cleared (no exception flags set, TOP is set to 0). The data registers in the register stack are left unchanged, but they are all tagged as empty (11B). Both the instruction and data pointers are cleared.

The FINIT instruction checks for and handles any pending unmasked floating-point exceptions before performing the initialization; the FNINIT instruction does not.

Intel Architecture Compatibility

When operating a Pentium or Intel486 processor in MS-DOS compatibility mode, it is possible (under unusual circumstances) for an FNINIT instruction to be interrupted prior to being executed to handle a pending FPU exception. See the section titled “No-Wait FPU Instructions Can Get FPU Interrupt in Window”, for a description of these circumstances. An FNINIT instruction cannot be interrupted in this way on a Pentium Pro processor.

In the Intel387 math coprocessor, the FINIT/FNINIT instruction does not clear the instruction and data pointers.

Operation

```
FPUControlWord ← 037FH;
FPUStatusWord ← 0;
FPUTagWord ← FFFFH;
FPUDataPointer ← 0;
FPUInstructionPointer ← 0;
FPULastInstructionOpcode ← 0;
```

FPU Flags Affected

C0, C1, C2, C3 cleared to 0.

Floating-Point Exceptions

None.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

44.20 FIST/FISTP—Store Integer

Opcode	Instruction	Description
DF /2	FIST *m16int*	Store ST(0) in *m16int*
DB /2	FIST *m32int*	Store ST(0) in *m32int*
DF /3	FISTP *m16int*	Store ST(0) in *m16int* and pop register stack
DB /3	FISTP *m32int*	Store ST(0) in *m32int* and pop register stack
DF /7	FISTP *m64int*	Store ST(0) in *m64int* and pop register stack

Description

The FIST instruction converts the value in the ST(0) register to a signed integer and stores the result in the destination operand. Values can be stored in word- or short-integer format. The destination operand specifies the address where the first byte of the destination value is to be stored.

The FISTP instruction performs the same operation as the FIST instruction and then pops the register stack. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1. The FISTP instruction can also stores values in long-integer format.

The following table shows the results obtained when storing various classes of numbers in integer format.

ST(0)	DEST
-•	*
–F < –1	–I
–1 < –F < –0	**
–0	0
+0	0
+0 < +F < +1	**
+F > +1	+I
+∞	*
NaN	*

NOTES:
1. FMeans finite-real number.
2. IMeans integer.
3. *Indicates floating-point invalid-operation (#IA) exception.
4. **0 or ±1, depending on the rounding mode.

If the source value is a non-integral value, it is rounded to an integer value, according to the rounding mode specified by the RC field of the FPU control word.

If the value being stored is too large for the destination format, is an ∞, is a NaN, or is in an unsupported format and if the invalid-arithmetic-operand exception (#IA) is unmasked, an invalid-operation exception is generated and no value is stored in the destination operand. If the invalid-operation exception is masked, the integer indefinite value is stored in the destination operand.

Operation

```
DEST ← Integer(ST(0));
IF instruction = FISTP
    THEN
        PopRegisterStack;
FI;
```

FPU Flags Affected

C1	Set to 0 if stack underflow occurred.
	Indicates rounding direction of if the inexact exception (#P) is generated: 0 = not roundup; 1 = roundup.
	Cleared to 0 otherwise.
C0, C2, C3	Undefined.

Floating-Point Exceptions

#IS	Stack underflow occurred.
#IA	Source operand is too large for the destination format
	Source operand is a NaN value or unsupported format.
#P	Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#GP(0)	If the destination is located in a nonwritable segment.
	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register is used to access memory and it contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.21 FLD—Load Real

Opcode	Instruction	Description
D9 /0	FLD *m32real*	Push *m32real* onto the FPU register stack.
DD /0	FLD *m64real*	Push *m64real* onto the FPU register stack.
DB /5	FLD *m80real*	Push *m80real* onto the FPU register stack.
D9 C0+i	FLD ST(i)	Push ST(i) onto the FPU register stack.

Description

Pushes the source operand onto the FPU register stack. If the source operand is in single- or double-real format, it is automatically converted to the extended-real format before being pushed on the stack.

The FLD instruction can also push the value in a selected FPU register [ST(i)] onto the stack. Here, pushing register ST(0) duplicates the stack top.

Operation

```
IF SRC is ST(i)
    THEN
        temp ← ST(i)
TOP ← TOP – 1;
IF SRC is memory-operand
    THEN
        ST(0) ← ExtendedReal(SRC);
    ELSE (* SRC is ST(i) *)
        ST(0) ← temp;
```

FPU Flags Affected

C1	Set to 1 if stack overflow occurred; otherwise, cleared to 0.
C0, C2, C3	Undefined.

Floating-Point Exceptions

#IS	Stack overflow occurred.
#IA	Source operand is an SNaN value or unsupported format.
#D	Source operand is a denormal value. Does not occur if the source operand is in extended-real format.

Protected Mode Exceptions

#GP(0)	If destination is located in a nonwritable segment.
	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register is used to access memory and it contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.22 FLD1/FLDL2T/FLDL2E/FLDPI/FLDLG2/FLDLN2/ FLDZ—Load Constant

Opcode	Instruction	Description
D9 E8	FLD1	Push +1.0 onto the FPU register stack.
D9 E9	FLDL2T	Push $\log_2 10$ onto the FPU register stack.
D9 EA	FLDL2E	Push $\log_2 e$ onto the FPU register stack.
D9 EB	FLDPI	Push π onto the FPU register stack.
D9 EC	FLDLG2	Push $\log_{10} 2$ onto the FPU register stack.
D9 ED	FLDLN2	Push $\log_e 2$ onto the FPU register stack.
D9 EE	FLDZ	Push +0.0 onto the FPU register stack.

Description

Push one of seven commonly used constants (in extended-real format) onto the FPU register stack. The constants that can be loaded with these instructions include +1.0, +0.0, $\log_2 10$, $\log_2 e$, π, $\log_{10} 2$, and $\log_e 2$. For each constant, an internal 66-bit constant is rounded (as specified by the RC field in the FPU control word) to external-real format. The inexact-result exception (#P) is not generated as a result of the rounding.

See the section titled "Pi", for a description of the π constant.

Operation

```
TOP ← TOP – 1;
ST(0) ← CONSTANT;
```

FPU Flags Affected

C1 Set to 1 if stack overflow occurred; otherwise, cleared to 0.

C0, C2, C3 Undefined.

Floating-Point Exceptions

#IS Stack overflow occurred.

Protected Mode Exceptions

#NM EM or TS in CR0 is set.

Real-Address Mode Exceptions

#NM EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#NM EM or TS in CR0 is set.

Intel Architecture Compatibility

When the RC field is set to round-to-nearest, the FPU produces the same constants that is produced by the Intel 8087 and Intel287 math coprocessors.

44.23 FLDCW—Load Control Word

Opcode	Instruction	Description
D9 /5	FLDCW m2byte	Load FPU control word from *m2byte.*

Description

Loads the 16-bit source operand into the FPU control word. The source operand is a memory location. This instruction is typically used to establish or change the FPU's mode of operation.

If one or more exception flags are set in the FPU status word prior to loading a new FPU control word and the new control word unmasks one or more of those exceptions, a floating-point exception will be generated upon execution of the next floating-point instruction (except for the no-wait floating-point instructions, see the section titled “Software Exception Handling”). To avoid raising exceptions when changing FPU operating modes, clear any pending exceptions (using the FCLEX or FNCLEX instruction) before loading the new control word.

Operation

```
FPUControlWord ← SRC;
```

FPU Flags Affected

C0, C1, C2, C3 undefined.

Floating-Point Exceptions

None; however, this operation might unmask a pending exception in the FPU status word. That exception is then generated upon execution of the next “waiting” floating-point instruction.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register is used to access memory and it contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.24 FLDENV—Load FPU Environment

Opcode	Instruction	Description
D9 /4	FLDENV *m14/28byte*	Load FPU environment from *m14byte* or *m28byte*.

Description

Loads the complete FPU operating environment from memory into the FPU registers. The source operand specifies the first byte of the operating-environment data in memory. This data is typically written to the specified memory location by a FSTENV or FNSTENV instruction.

The FPU operating environment consists of the FPU control word, status word, tag word, instruction pointer, data pointer, and last opcode. Figures “Protected Mode FPU State Image in Memory, 32-Bit Format” through “Real Mode FPU State Image in Memory, 16-Bit Format” , show the layout in memory of the loaded environment, depending on the operating mode of the processor (protected or real) and the current operand-size attribute (16-bit or 32-bit). In virtual-8086 mode, the real mode layouts are used.

The FLDENV instruction should be executed in the same operating mode as the corresponding FSTENV/FNSTENV instruction.

If one or more unmasked exception flags are set in the new FPU status word, a floating-point exception will be generated upon execution of the next floating-point instruction (except for the no-wait floating-point instructions, see the section titled “Software Exception Handling”). To avoid generating exceptions when loading a new environment, clear all the exception flags in the FPU status word that is being loaded.

Operation

```
FPUControlWord ← SRC(FPUControlWord);
FPUStatusWord ← SRC(FPUStatusWord);
FPUTagWord ← SRC(FPUTagWord);
FPUDataPointer ← SRC(FPUDataPointer);
FPUInstructionPointer ← SRC(FPUInstructionPointer);
FPULastInstructionOpcode ← SRC(FPULastInstructionOpcode);
```

FPU Flags Affected

The C0, C1, C2, C3 flags are loaded.

Floating-Point Exceptions

None; however, if an unmasked exception is loaded in the status word, it is generated upon execution of the next “waiting” floating-point instruction.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register is used to access memory and it contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.

44.25 FMUL/FMULP/FIMUL—Multiply

Opcode	Instruction	Description
D8 /1	FMUL *m32real*	Multiply ST(0) by *m32real* and store result in ST(0)
DC /1	FMUL *m64real*	Multiply ST(0) by *m64real* and store result in ST(0)
D8 C8+i	FMUL ST(0), ST(i)	Multiply ST(0) by ST(i) and store result in ST(0)
DC C8+i	FMUL ST(i), ST(0)	Multiply ST(i) by ST(0) and store result in ST(i)
DE C8+i	FMULP ST(i), ST(0)	Multiply ST(i) by ST(0), store result in ST(i), and pop the register stack
DE C9	FMULP	Multiply ST(1) by ST(0), store result in ST(1), and pop the register stack
DA /1	FIMUL *m32int*	Multiply ST(0) by *m32int* and store result in ST(0)
DE /1	FIMUL *m16int*	Multiply ST(0) by *m16int* and store result in ST(0)

Description

Multiplies the destination and source operands and stores the product in the destination location. The destination operand is always an FPU data register; the source operand can be an FPU data register or a memory location. Source operands in memory can be in single-real, double-real, word-integer, or short-integer formats.

The no-operand version of the instruction multiplies the contents of the ST(1) register by the contents of the ST(0) register and stores the product in the ST(1) register. The one-operand version multiplies the contents of the ST(0) register by the contents of a memory location (either a real or an integer value) and stores the product in the ST(0) register. The two-operand version, multiplies the contents of the ST(0) register by the contents of the ST(i) register, or vice versa, with the result being stored in the register specified with the first operand (the destination operand).

The FMULP instructions perform the additional operation of popping the FPU register stack after storing the product. To pop the register stack, the processor marks the ST(0) register as empty and increments the stack pointer (TOP) by 1. The no-operand version of the floating-point multiply instructions always results in the register stack being popped. In some assemblers, the mnemonic for this instruction is FMUL rather than FMULP.

The FIMUL instructions convert an integer source operand to extended-real format before performing the multiplication.

The sign of the result is always the exclusive-OR of the source signs, even if one or more of the values being multiplied is 0 or ∞. When the source operand is an integer 0, it is treated as a +0.

The following table shows the results obtained when multiplying various classes of numbers, assuming that neither overflow nor underflow occurs.

		DEST						
		-•	–F	–0	+0	+F	+∞	NaN
SRC	-•	+∞	+∞	*	*	-•	-•	NaN
	–F	+∞	+F	+0	–0	–F	-•	NaN
	–I	+∞	+F	+0	–0	–F	-•	NaN
	–0	*	+0	+0	–0	–0	*	NaN
	+0	*	–0	–0	+0	+0	*	NaN
	+I	-•	–F	–0	+0	+F	+∞	NaN
	+F	-•	–F	–0	+0	+F	+∞	NaN
	+∞	-•	-•	*	*	+∞	+∞	NaN
	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN

NOTES:
1. FMeans finite-real number.
2. IMeans Integer.
3. *Indicates invalid-arithmetic-operand (#IA) exception.

Operation

```
IF instruction is FIMUL
    THEN
        DEST ← DEST * ConvertExtendedReal(SRC);
    ELSE (* source operand is real number *)
        DEST ← DEST * SRC;
FI;
IF instruction = FMULP
    THEN
        PopRegisterStack
FI;
```

FPU Flags Affected

C1 — Set to 0 if stack underflow occurred.

Indicates rounding direction if the inexact-result exception (#P) fault is generated: 0 = not roundup; 1 = roundup.

C0, C2, C3 — Undefined.

Floating-Point Exceptions

#IS	Stack underflow occurred.
#IA	Operand is an SNaN value or unsupported format.
	One operand is ±0 and the other is ±∞.
#D	Source operand is a denormal value.
#U	Result is too small for destination format.
#O	Result is too large for destination format.
#P	Value cannot be represented exactly in destination format.

Protected Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
	If the DS, ES, FS, or GS register is used to access memory and it contains a null segment selector.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made while the current privilege level is 3.

Real-Address Mode Exceptions

#GP	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.

Virtual-8086 Mode Exceptions

#GP(0)	If a memory operand effective address is outside the CS, DS, ES, FS, or GS segment limit.
#SS(0)	If a memory operand effective address is outside the SS segment limit.
#NM	EM or TS in CR0 is set.
#PF(fault-code)	If a page fault occurs.
#AC(0)	If alignment checking is enabled and an unaligned memory reference is made.